AMYGDALA

$z \mapsto z^2 + c$

A Newsletter of fractals & $\mathcal{M}$ -- the Mandelbrot Set
AMYGDALA, Box 219, San Cristobal, NM 87564
505/758-7461

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CORRECTION

Two of the slide descriptions which appeared in Amygdala #7 need comment or correction. Slide #177 lacks the "Red Dawn" which appears as a series of broad reddish background stripes in the similar (but undistributed) slide #181, making the description of #177 a tad incomprehensible. J.D. Jones informs me that slide #203 "is not a Julia set, exactly, it's the difference between two adjacent Julia sets."

FULL MOON, OCTOBER 1987

One yellow leaf brushes my face,
edges rounded like almondbread with ice,
calls
every leaf on the tree's round edge
scudding in the sky on a summer afternoon,
and every leaf that might edge on these clouds
calls
every tree's leaf that falls in this moonlit night,
treetops and valleys golden and red
where a lady laments years many as leaves,
calls
every leaf of all these long trees' summers,
moulded in the snows of every year,
calls
every leaf that can ever be stone or burning,
on Mazon Creek, or in the nuclear fire,
calls
in the darkening sky, the first full moon of autumn,
shining dark object, turning on its icy needle.
- *Robert S. Richmond*

NOBLE WORK

Looking back, a few of you will realize that you have been getting the newsletter gratis, perhaps with the slides as well. Please consider sending a *contribution* to Amygdala to help us continue our noble work.

Now that I warm to the subject, perhaps your large, affluent company would consider a large *donation*, to help us *expand* our noble work! The first item on our agenda is to purchase a Macintosh II with color monitor, so we can generate a number of interesting fractal images that have been waiting on the back burner. About $8K will do it.

AUTHOR!

If you submit something for publication in *Amygdala*, please include a brief biographical sketch, if you don't mind. I suspect Amy readers would like to know something about you!

THE SLIDES

The color slide supplement continues with four more slides sent to subscribers with this issue. #202 was done by John Dewey Jones; the rest are by Ken Philip, who notes that #406 was done with the new version of Robert Woodhead's MandelColor, which now has a 'contrast' CLUT option.

#202: Lovely lacy white Julia set on cobalt ground. Fascinating in spite of (or because of?) the minimal coloring scheme.

#380: Marvelous yellow-brown body containing single- and triple-structured centromeres, with six stubby limbs three of which are five-stars. Shaded lime-green background.

#387: A fascinating alternate view of the structure of the utter West.

#406: A midget $\mathcal{M}$ surrounded by scalloped shells, with center at -1.999435. The marked difference in contours between this midget and John Dewey Jones' slide of the -1.99638 midget is due to the difference in escape radius — Jones was using E.R. = 2, whereas #406 has E.R. = 100.

KEN PHILIP'S SLIDE NOTES

Slides #343, #347, and #375 were created by Ken Philip, but his notes on them arrived too late to be included in Amy #7. Here they are now.

Dear Rollo:
Enclosed is a sheet giving the data on the slides. Please note that the corner coordinates given are for the original screens — the photos did not quite cover the whole screen (so as not to show menu bars and such).
I called Robert Woodhead, and got his approval for using the slides, provided that you include a notice to the effect that these slides were made using the program *MandelColor*, copyrighted 1987 by Robert Woodhead. This would apply to slides A307, A319, A321, A343, and A375. I would suggest that for the other slides in your list you also include a note that they were made using the program Mandel881 by Stephen Eubank (A344, A347, A348, A349, and A365). That way you're covered.
You might want to note that both these programs are available from CompuServe (and I think I sent copies of the old versions to you as well).
Woodhead has set up a fund to provide computers to visually handicapped students, called *The Vision Fund.* The sole source of income for this fund is shareware contributions from users of his programs. I am sure he would be grateful if you included the address of this fund:

The Vision Fund
c/o Sir-Tech
Charlestown Ogdensburg Mall
Ogdensburg, NY 13669

and mention that anyone who finds these slides enjoyable is welcome to send a small contribution... [See ABOUT MANDELCOLOR, below.]
Note that I included the value of the 'escape radius' in the list of parameters. This refers to my previous letter, in which I pointed out that the value of the escape radius controls the appearance of the contours. [See ESCAPE RADIUS, below.]
In all cases the dwell limit is 64.

slide	R	center	magnif.	aspect
A343	100	-0.5621967613+0.6429073556i	$20\text{x}10^9$	2.000
A347	2	-1.6739100000-0.0005350000i	92	1.186
A375	100	-0.1986162751+1.1003460664i	$2\text{x}10^9$	2.800

ESCAPE RADIUS

Most calculations of dwell limit have used $|z_i| > 2$ as a criterion of "escape", i.e. that z_0 is not in $\mathcal{M}$. More generally, you can use any $R \geq 2$ as an "escape radius", that is, use $|z_i| > R$ as the escape criterion. R = 100, for example, produces interesting variations on familiar scenes. A more detailed article on this will appear in a later issue.

ABOUT MANDELCOLOR

All of you who are using Woodhead's MandelColor program should be interested in the following letter:

Sir-Tech Software, Inc.
PO Box 245
Ogdensburg, NY 13669

Kenelm W. Philip
1590 North Becker Ridge Road
Fairbanks, AK 99709

Dear Mr. Philip:

First, we would like to begin by offering to you our sincere appreciation and gratitude for your contribution to the Donald Beaulieu Vision Fund. We have deposited your check into a separate account especially created for Mr. Donald Beaulieu.

The funds which we are collecting will go toward the purchase of a Visualtek reading machine for Donald. Because Donald has only ten percent vision, he is considered legally blind. With the aid of the Visualtek machine, Donald will be better able to read printed text and also the screen images from his computer monitor. The Visualtek machine magnifies print 60 times the normal size and then displays it in the enlarged form on a monitor. This enables a visually handicapped person to read virtually anything in print form with ease.

Donald graduated from his hometown high school with honors. He would like to be able to go on to college, but needs this machine to enable him to do the reading required for college studies. He is unable to enter college without this machine and yet he has been unable also to receive aid to purchase this machine. The approximate cost of the Visualtek reading machine ranges between $2,600 and $5,000. Donald has been able to raise by himself $300 over the past year and a half. With your help, we will be able to ensure that Donald receives this much-needed equipment and can continue on with his education and a happier future.

Because of the high expense of this equipment as compared to the donations we ask, there remains a possibility of not reaching our goals. if it becomes apparent that our goals will not be met, we will refund all donations received.

Again, thank you for your contribution. We, Donald, and the Beaulieu family appreciate your contribution and are overjoyed that people such as yourselves have made the effort to help Donald reach his goals.
With kind regards,

Sincerely,
Norman Sirotek and Staff
SIR-TECH SOFTWARE, INC.

TUTORIAL: CONJUGATION

The *complex conjugate* of a complex number $z = a + ib$ is the complex number $a - ib$, denoted by z^*. A complex number is real if and only if it is equal to its conjugate. Note that the conjugate of z^* is z itself. The real and imaginary part of z can be expressed in terms of z and z^*:

$$\mathrm{Re}\, z = (z + z^*)/2, \quad \mathrm{Im}\, z = (z - z^*)/2i.$$

Conjugation "distributes" over the arithmetic operations:

$$(z+w)^* = z^* + w^*, \quad (z-w)^* = z^* - w^*, \quad (zw)^* = z^* \cdot w^*,$$
$$(z/w)^* = z^* / w^*,$$

and this can be extended over all rational operations.

As an application, if z is a root of the equation

$$c_0z^n + c_1z^{n-1} + \ldots + c_{n-1}z + c_n = 0,$$

then z^* is a root of the "conjugate" equation:

$$c_0^*z^n + c_1^*z^{n-1} + \ldots + c_{n-1}^*z + c_n^* = 0,$$

If the coefficients c_i are all real, hence self-conjugate, then z and z^* are roots of the same equation. As a result we have that the non-real roots of an equation with real coefficients occur in pairs of conjugate roots.

The product $zz^* = a^2 + b^2$ is always positive or zero. Its non-negative square root is called the *modulus* or *absolute value* of the complex number z, and is designated $|z|$, which is consistent with the definition of absolute value for real numbers. Thus $zz^* = |z|^2$, where $|z| \geq 0$, and $|z^*| = |z|$.

Since $|zw|^2 = zw \cdot (zw)^* = zwz^*w^* = zz^*ww^* = |z|^2|w|^2$, we have:

$$|zw| = |z| \cdot |w|,$$

since both are ≥ 0; i.e. the modulus of a product is the product of the moduli. We can extend this to arbitrarily many factors:

$$|z_1z_2 \ldots z_n| = |z_1| \cdot |z_2| \cdot \ldots \cdot |z_n|.$$

The quotient z/w (where $w \neq 0$) satisfies $w(z/w) = z$, so $|w| \cdot |z/w| = |z|$; therefore

$$|z/w| = |z| / |w|.$$

Things are not quite so neat for the modulus of a sum:

$$|z+w|^2 = (z+w)(z+w)^* = zz^* + (zw^* + wz^*) + ww^*,$$

or

$$|z+w|^2 = |z|^2 + |w|^2 + 2\,\mathrm{Re}\, zw.$$

For the modulus of a difference:

$$|z-w|^2 = |z|^2 + |w|^2 - 2\,\mathrm{Re}\, zw.$$

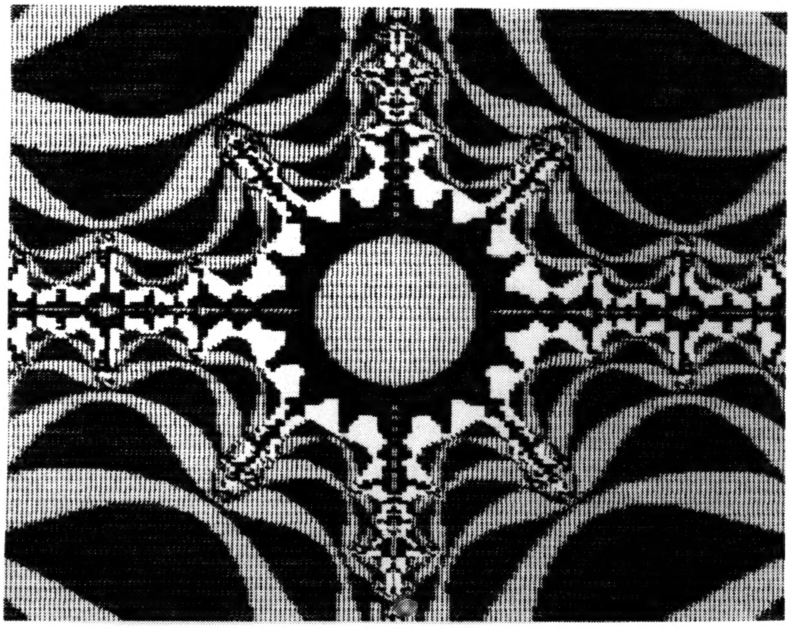
Adding these last two formulas, we get:

$$|z+w|^2 + |z-w|^2 = 2(|z|^2 + |w|^2).$$

FRACTAL CALENDAR — 1988

James E. Loyless has created a fractal calendar for 1988 and sent me a copy. It has one 8.5" x 14" page for each month, from January through December. Each page has a black & white fractal picture in the upper half, and an inscription and calendar in the lower half.

The picture for June is shown below. The inscription is: "Cancer, the Aztec God of Sun and Moon. All praise the month of June; month of the longest day; month that divides the joys of Spring and the blessings of Summer; month of children's delight and bride's fancy; month of bliss and happiness. The Aztec is actually the eye of a much larger mu dragon. The warmth that he radiates splits the heavens into even segments, compass style, and thence into ripples of happy light. He guides and encourages the Summer traveler, both in day and in night."



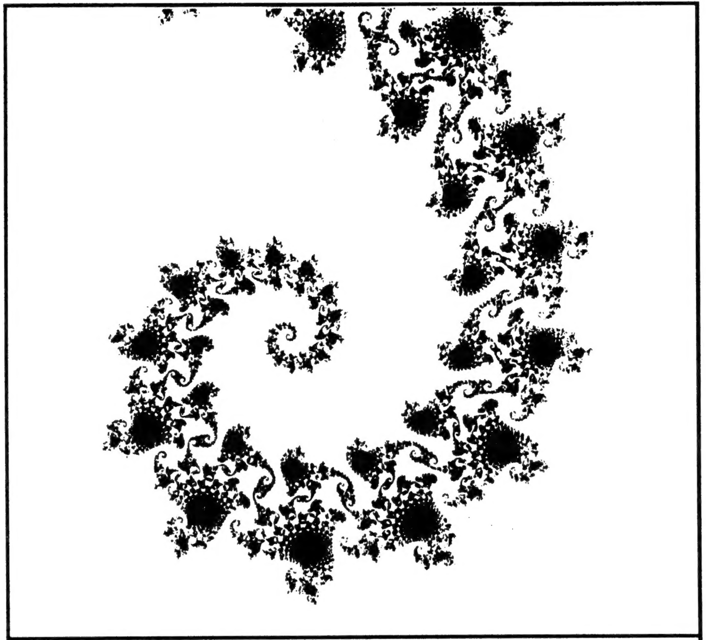
If you'd like a copy of this delightful calendar, send your name and address with $2.00 to:

James E. Loyless
5185 Ashford Court
Lilburn, Georgia 30247

In a letter dated November 9, 1987, Jim Loyless writes:

Regarding the Fractal Calendar ... I'm not really interested in making a profit, but mainly want to spread interest in this remarkable new field of fun mathematics.

By Christmas I should be esconced with a new XT clone, complete with EGA, co-processor, turbo clock, hard disk, and a decent printer. So you'll probably see some more creative and higher resolution work from me. Maybe you'll want to print some of it. I plan to concentrate on exploring worlds other than $z \mapsto z^2+c$. (Did you know that variations on z^3+kz^2 have some interesting features?) In the meantime, I've run some higher resolution (480x400) items on the old Commodore, which I can only view from the printer, and copies are attached for your review. [See figure below.]



-0.74425+.13066i ... -0.74245+0.13215; iter. limit 160.
Resolution 480x399 (cropped to 418x399).
Black = 160, white < 160.

ORDER IN CHAOS (1)

Martin Gardner

Nature's patterns are marvelous mixtures of order and chaos. The moon looks perfectly round, but, through a telescope, its circumference is jagged. In quiet air, the smoke from a pipe rises in a fairly straight plume, then quickly dissolves into disheveled swirls. The earth follows an almost perfect ellipse around the sun, but its coastlines, rivers and lightning bolts twist anywhither.

Now there is nothing new about these observations, but about 25 years ago, mathematicians and physicists began to make some remarkable discoveries. Physicists found that many natural phenomena that display random behavior are not immune to simple mathematical theorems. And mathematicians found that trivial equations can describe the movement of a point that is indistinguishable from random behavior. There is order behind the chaos of the physical world, and chaos contaminates elementary algebra. Called *chaos theory,* it is now one of the hottest new areas of research. its unexpected laws are finding important applications to such diverse, seemingly random phenomena as weather prediction, air and liquid turbulence, oscillating chemical reactions, heart disorders, cancer growth, epilepsy, evolution, computer breakdowns and the Great Red Spot on Jupiter.

Chaos: Making a New Science (Viking 1987), by the *New York Times* science writer James Gleick, is the first popularly written book about this fascinating, rapidly growing discipline. It is a splendid introduction. Not only does it explain accurately and skillfully the fundamentals of chaos theory, but it also sketches the theory's colorful history, with entertaining anecdotes about its pioneers and provocative asides about the philosophy of science and mathematics.

The book opens with the story of how Edward Lorentz, a meteorologist at MIT, discovered in the early 1960s the first of what came to be called "strange attractors." But first, what is an ordinary attractor? Imagine a rigid pendulum, swinging back and forth without friction or air resistance. If you plot its perpetual movement on a coordinate plane (one axis for position, the other for velocity), the bob's trajectory is a circle. This circle is the bob's attractor, the path to which its behavior is confined. If you add friction to the pendulum, it soon stops. Its path now graphs as a spiral. The attractor is the fixed point at the spiral's center.

What Lorentz discovered was a completely new kind of attractor. Imagine a wheel on which buckets hang. A stream of water at the top of the wheel fills them with water at a steady rate when they are at the top, and they lose water at a steady rate through a small hole. Lorentz proved that when the two rates have certain values, the wheel's motion becomes utterly chaotic, and in a way closely related to convection currents. If the wheel's motion is plotted as the movement of a point in what physicists call a three-dimensional phase space, the point's trajectory — the wheel's strange attractor — turns out to be an infinitely long double spiral that resembles butterfly wings. The curve never self-intersects. This means that the wheel's behavior, as it randomly alters speed and direction, never repeats in a predictable way. Lorentz, Gleick tells us, actually built a wheel model in his basement to convince skeptics that such a simple deterministic system would behave chaotically.

When a physical system is described by linear equations — those with no exponents other than one or zero — the equations graph as straight lines, and the system's behavior is orderly and predictable. Equations with other exponents are called *nonlinear*. Most natural phenomena are described by nonlinear equations, especially by the nonlinear differential equations of calculus. It is only in nonlinear systems that chaotic behavior appears, constrained or "bounded" by strange attractors when the behavior is modeled by points in a phase space. It turns out that these chaotic attractors are fractals — curves of infinite complexity, usually self-similar in the strange sense that, like coastlines, they display the same form when portions are magnified.

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(1) This review originally appeard in the Boston Sunday Globe, October 4, 1987.

Many of these strange attractors arise from a process called "periodic doubling" or "bifurcation" that is similar to what happens when taffy is stretched and folded by a taffy machine, or to playing cards when an ordered deck is repeatedly shuffled. Spots close together in the taffy (or cards in the deck) rapidly diverge and wander about in a random way. If certain nonlinear systems are modeled in phase space, an analogous stretch-and-fold process occurs as the system "bifurcates into chaos." A strange attractor called Smale's horseshoe (after mathematician Stephen Smale) was the earliest attractor related to this particular road to chaos (there are many others). Bifurcation is controlled by a universal constant (an irrational number with a value of 4.6692+) called a Feigenbaum number after its discoverer, Mitchell Feigenbaum. Trajectories diverge so rapidly on this road to chaos that tiny variations of initial conditions are quickly magnified. Meteorologists call it the *butterfly effect* because it has been said that the flutter of a butterfly's wings could trigger a causal cascade that would produce a tornado. It is this effect that renders long-range weather prediction intrinsically impossible.

Lorentz's discovery sparked an intensive search for other chaotic systems bounded by other strange attractors. Because a computer screen provides a way of modeling chaos if it is simple enough, the computer quickly became such a powerful research tool that much of chaos theory has come from mathematicians sitting alone at computer consoles and experimenting with low-order nonlinear equations. When different colors are used to distinguish aspects of chaos, extraordinarily complex and beautiful patterns emerge. Gleick's book has eight color plates of these dazzling designs. Especially exquisite are the fractal Julia sets (after the French mathematician Gaston Julia) that separate regions of chaos from what are called basins of attraction. Named strange repellers because they repel points rather than attract, they are intimately related to the famous Mandelbrot set discovered in 1979 by IBM's Benoit Mandelbrot. It was Mandelbrot who coined the term fractal, and who was the first to investigate fractals in depth.

The Mandelbrot set, generated by an absurdly simple procedure that involves the continual squaring and adding of complex numbers, differs from all other fractals in the following bizarre way. Each new magnification introduces unpredictable change. The set has been likened to an incredible jungle of exotic flora and fauna which mathematicians have only started to explore. Because its delicate filigree of flames and spirals goes to infinity, its properties may never become fully known. It is a thing of strange beauty and awesome complexity, containing endless depths of wild surprises. Gleick rightly regards it as the most mysterious object in geometry. "A devil's polymer," Mandelbrot has called it.

Ten years ago there was a great burst of interest in a new branch of topology called catastrophe theory. Some have speculated that this enthusiasm was generated in part by the theory's colorful name. Is the term "chaos" playing a similar role? Would chaos theory have been embraced so fervidly by young computer hackers if it had been called say, "nonlinear bounded randomness"?

Some chaos evangelists have suggested, and Gleick is inclined to agree, that chaos theory is a revolution destined to alter physics as drastically as it was altered by relativity theory and quantum mechanics. Or will chaos fade into just another, albeit fascinating, aspect of probability theory, or perhaps an aspect of fractal theory? Only time will tell.

PENROSE ON ℳ

In an interview by *Omni* (June 1986) the British mathematical physicist Roger Penrose invoked the Mandelbrot set to support his Platonic approach to mathematics:

Have you ever seen those pictures produced by computers, the object known as the Mandelbrot set? It's as if you're traveling to some distant world. You turn on your sensing device and see this incredibly complicated configuration, with all sorts of structure to it, and you try to figure out what it is. You might think it is some extraordinary landscape or perhaps some kind of creature with lots of little babies all over the place, babies that are almost but not quite the same as the creature itself. Very elaborate and impressive! Yet just from seeing the equations, nobody had the remotest conception that they would produce patterns of this nature. now these landscapes aren't conjured up out of someone's imagination: everyone sees the same pattern. You're exploring something with a computer, but it's not dissimilar from exploring something with experimental apparatus.

MORE ON "AMYGDALA"

—from John Dewey Jones

"... But the Parsee came down from his palm-tree, wearing his hat, from which the rays of the sun were reflected in more-than-oriental splendour, packed up his cooking stove, and went away in the direction of Orotavo, Amygdala, the Upland Meadows of Anantarivo, and the marshes of Sonaput..."

— from "How the Rhinoceros got his Skin", *Just So Stories,* Rudyard Kipling

A LETTER FROM RUDY RUCKER

December 8, 1987

Dear Rollo and Amygdala,

I'm glad the issues are still coming. Here's some news about the mandelbrot set in Silicon Valley.

Mark Bolme of Sintar kindly sent me a test copy of his mandelbrot set program, Fractal Magic. It produces really fine slides both CGA and EGA and is easy to use. A flaw in his program is that it does not show the mandelbrot set being drawn pixel by pixel, so you don't know till the run is over if you have set things up properly.

The first mandelbrot set program I played with was Marshall Dudley's shareware program Superman. I still have an emotional attachment to this program, even though it is not very fast. Dudley does have an 8087 upgrade available.

I saw some really great mandelbrot images by Buck Medwick at SCO (The Santa Cruz Operation, who wrote Xenix, I believe). These were VGA images, with even more detail than EGA. They had found some new (non-Peitgen) shapes, notably a square spiral. Instead of just hanging out in seahorse valley, they had ventured into the ”asshole” of the mandelbrot set. (I think we should accept the fact that it really isn't a cardioid, it's an ass!)

I just got AutoCad with AutoShade, which comes with an awesomely fast (80287 dependent) mandelbrot set program that pretty much blows all competitors away. John Walker of AutoDesk recently ran a variant of the program on six Suns for a weekend and got a thousandfold zoom in 640 EGA frames into seahorse valley. The file exists as a 5 megabyte slideshow which can be copied and run on any clone with enough hard disk space.

The Math and Computer Science Department organized a Weird Screens Festival here at San Jose State last month, and one of the most remarkable entries was a printout a Chinese highschool kid brought in. It was an incredibly detailed black and white zoom on the mandelbrot set. “How long did this take you to make?” I asked him. “Six weeks. My brother & I ran it on an XT.” “And then you printed it?” “No, the printer was on the whole time. Every few hours it would print a dot.” Needless to say, he wouldn't let the picture out of his hands. We hope to have the festival again next year.

Inspired by John Dewey Jones, I recently wrote a science fiction story called “The Mandelbrot Set,” which includes the following relevant passages [see item following].

I wonder if anyone has good ideas about how to mathematically describe the object that is needed in this story. The idea is to have a three dimensional shape some of whose cross-sections are just like cross sections of the mandelbrot set, although the object is not a simple rotation of the M-set. What is wanted is something like a mandelbrot set crossed with a mandelbrot disk.

EXCERPTS FROM A STORY CALLED “THE MANDELBROT SET”

— *Rudy Rucker*

Plants are really where it's at, no lie. Take an oaktree: it grows from an acorn, right? The acorn is the program and the oaktree is the output. The runtime is like 80 years. That's the best kind of computation ... where a short program runs for a long time and makes an interesting image. The universe itself is probably like that — a simple start and a long computation. In information theory we call that low complexity / high depth. Low complexity means short program, and high depth means a long runtime.

A really good example of a low complexity / high depth pattern is the Mandelbrot set. You grow it in the plane ... for each point you keep squaring and adding in the last value, and some points go out to infinity and some don't. The ones that don't are inside the Mandelbrot set which is a big warty ass-shape with a disk stuck onto it. There's an antenna sticking out of the disk, and shishkabobbed onto the antenna are tiny little Mandelbrot sets: ass, warts & disk. Each of the warts is a Mandelbrot disk, too, each with a wiggly antenna coming out, and with shishkabobs of ass, warts & disk, with yet smaller antennae, asses, warts, and disks, all swirled into maelstroms and lobed vortices, into paisley cactus high desert, into the Santa Cruz cliffs being eaten by the evercrashing sea.

* * *

The first odd thing I noticed was these like fireflies smacking into the windshield. The other odd thing was that the air was prickly, though I didn't consciously flash on that till later. It was prickly like before a storm when there's a lot of those good ions, you know, and your hairs stick up.

Meanwhile I was jamming down the road, with more and more of the bright little things whizzing up the slope at me, and then when I was about halfway downhill a giant light came up the hill towards me really fast. I thought it was a pig, and then I thought it was a lowflying plane. I got off the road onto the little piece of shoulder OK, but the sand was defective there and my front tire slid over into the ditch. The light was so big and bright that the car made a shadow on the embankment; and I'm thinking Oh God, they nuked San Jose. I remembered you go blind if you stare at a bomb blast, so I scrunched down and closed my eyes supertight.

And then nothing's happening, except there's a kind of hissing sound, really rich and complicated hissing — it's hard to explain — like a whole lot of radios doing soft static at once. I opened my eyes back up and the light was as strong as ever, but more like overhead now instead of behind me. That's when I decided it had to be a UFO.

I knew the aliens could do whatever they wanted, so I went ahead and got out of the car to get a good look at the ship. It was maybe fifty feet overhead and maybe fifty feet long. Or maybe a hundred and a hundred ... it was kind of hard to tell. There were zillions of those fireflies now; and the ones high off the ground and closer to the ship seemed larger. There were thin sort of tendrils connecting the fireflies to the ship so it was all sort of like a jellyfish overhead with bumpy tentacles hanging down, though by the time they got to the ground the tendrils were too small to see, so it looked like the “fireflies” weren't connected. I touched a couple of them ... they were tingly and hard to hold on to. The mothership just stayed up there, hissing and with all its tendrils wafting this way and that, like beautiful strings of Tivoli lights flashing red, yellow and green.

The ship itself was shaped in three main parts. There was a great big back section with a dimple in it, and then there was a smaller spherical section attached opposite the dimple, and sticking out of the front of the sphere section was a long spike kind of thing. It was like a beetle in a way, with the big part for abdomen, the sphere for thorax and the spike for head. I was a zoology major in college. A cross between a beetle and a jellyfish.

The UFO seemed to get lower and then some of the tendrils were brushing against me and I suddenly flashed that the prickly feeling I'd been getting was from invisible fine tendrils that I couldn't see. Could it be possible that thing was going to eat me like a Portuguese man-of-war that's got hold of a small fish?

The tendrils were all around me now, and the fireflies on the tendrils were as big as grapefruits and baseballs. The odd thing was that each of them was a big dimpled round part with a little sphere and with a thick little spike sticking out along the tendril. I took one of the baby globbies in my hands and peered at it. It was warm and jittery as a pet mouse. Even though the globbie was vague at the edges, it was solid in the middle.

* * *

After I snapped the tendril connecting the thingie to the big Mandelbrot UFO it began making a screaming noise and pulsing in ugly colors. Where before it had been colored a lovely red-yellow-green, now the big creature was all ugly cyan-white-magenta. The broken tendril that had led from the mothership to the baby was lashing about overhead, sputtering black and white sparks: checkerboard sparks, if you can visualize that.

BIBLIOGRAPHY

58. A Douady, "Algorithms for Computing Angles in the Mandelbrot Set", in *Chaotic Dynamics and Fractals,* Academic Press, Orlando Florida (1986).

59. J Weber, "Macintosh MacMand", *Personal Computer World* 9,12 (Dec 1986) 225-232. ["Presents a program for the Macintosh that is designed to accompany the article on page 196 on fractals and Julia sets." (See reference 31)]

60. PB Schroeder, "Plotting the Mandelbrot set", *BYTE* 11,13 (Dec 1986) 207-210. "The more interesting the display, the longer it takes to generate." ["Explores the Mandelbrot set on an Amiga. Describes what it is, the odd qualities of fractals, and the program provided that produces these sets graphically. Fractals can be used to 'describe the fragmentary aspects of nature' such as shoreline decay. 3 screen displays, 3 references."]

61. S Estvanik, "From fractals to graftals", *Computer Language* 3,7 (July 1986) 45-58. [Discusses fractals and graftals. Fractals show a large amount of detail at any level and are characterized by mathematical rigor and graphic dynamism. Graftals are procedural models of plants and trees. Both fractals and graftals have patterns that look the same no matter how close one looks at them. Examines graftal language elements and creating graftal images. Presents two programs that create graftals. 2 tables, 2 figures, 5 references."]

63. R Grehan, "Computers and music", *BYTE* 11,6 (June 1986) 143. ["Presents an introduction to 6 articles discussing current developments in music and computers." One of these is "Musical fractals (review #62).]

64. P Bass, "3-D fractals: three-dimensional ST landscapes", *ANTIC: The Atari resource* 4,12 (April 1986). ["A C language mouse-driven program that gives users a choice of creating 'two-dimensional or three-dimensional fractals in three color palettes and then saving the images to disk'. 4 photos."]

65. C Jackson, "Fractals for your Atari: Mathematics in picture form", *ANTIC: The Atari resource* 4,12 (April 1986) 10-13. ["Why study fractals? What is a fractal? An example. Hausdorff dimension. Julia curves. 1 figure."]

66. PW Carlson, "IBM fractal graphics", *Compute!* 8,3 (March 1986) 78-80. ["Presents 3 programs for use on IBM PC or PC Jr with color graphics adapter that demonstrate the use of fractals. Describes what a fractal is and what the programs do. 3 illustrations, 2 figures, 1 table."]

67. G Andrew, "Fractal generator", *Practical Computing* 8,12 (Dec 1985) 114-115. ["GRAPHICS column presents a BASIC program that allows users to create fractals. Includes coding for the BBC Micro. Provides some production rules. 7 figures."]

68. EI Lee, "Fractals for the PC", *PC Tech Journal* 3,11 (November 1985) 165-178. "These programs illustrate three methods for creating fractal curves using BASICA". ["Discusses creating fractals on an IBM PC with BASICA. Describes 3 methods for doing so: the direct array method, the array expansion method, and the string array method. 7 illustrations, 1 table, 5 references."]

69. D Cory, "More Efficient 3-D Fractals", *Creative Computing* 11,11 (Nov 1985) 6. ["Provides improvements to a program called '3-D Fractals' published in an earlier issue (Jul 1985). The BASIC code changes make the program much faster. Changes are for the Apple version."]

70. PW Carlson, "Apple Fractals", *Compute!* 7,9 (Sep 1985) 84-86. ["Fractals are curves and surfaces having fractional dimension. Using generators consisting of connected line segments, the three Apple II BASIC programs listed demonstrate plotting and replacing of line segments in self-contracting and self-avoiding curves. Theoretically this could continue infinitely. Screen resolution, however, confines the cycles of replacement. The Dragon Sweep illustrates the manner in which a fractal curve is filled. Eight Thousand

Dragons plots over 8,000 different dragons. The Snowflake Sweep uses a generator discovered by Mandelbrot to plot the sweep. 3 figures."]

71. M van de Panne, "Fractals: New dimensions in geometry", *80 Micro* 59 (Dec 1984) 114-117. ["Presents a BASIC program that lets the user create fractals on a TRS-80 Model I or III. The shapes are limited by the screen resolution. 7 photos."]

72. S Justice, "Fractals in focus", *80 Micro* 64, (May 1985) 59-60. "Produce fractals in intricate detail with this high-resolution program that draws striking geometric designs". ["Presents a BASIC program that lets users create high-resolution fractals. Requires a hi-res board and BASIC G to run on a TRS-80 models III and 4, and BBASIC and 32K to run on the Models 1000 and 1200. 12 figures." It is a modification of van de Panne's program: see #71]

73. SM Estvanik, "Fundamentals of fractals, part 2", *PC Magazine* 4,11 (May 28, 1985) 255-266. ["PROGRAMMING column presents a BASIC program that enables the user to draw graphic representations of irregular, real-world objects and the fractal algorithm on which it is based. Runs on the IBM PC. 2 illustrations."]

74. M McClure, "Computer illusions", *Popular Computing* 4,3 (Jan 1985) 49-52. "Fractals make mathematical magic in the movies". ["ADVANCED TECHNOLOGY column discusses the use of fractals for creating the graphics used in movies. Defines fractals and gives examples of those used in popular movies. Contains a BASIC program that demonstrates the technique. 1 illustration."]

75. L Solomon, "Sprites, moonmen and fractals", *Computers & Electronics* 22,12 (Dec 1984) 12. ["LES SOLOMON ON COMPUTER HARDWARE" column discusses the history of computer graphics as it applies to games and current accomplishments such as the film industry's super high resolution graphics and the use of fractal geometry. 1 illustration."]

76. S Wardrop, "Plotting fractals on your computer", *Micro: the 6502/6809 Journal* 70 (Mar 1984) 74-77. ["Plotting fractals (irregular shapes) can often produce beautiful, even spectacular results which call into question our common definition of length. Defines 'fractal', covers the snowflake curve, and more."]

77. D Thornburg, "A fractal of my former self", *Compute!* 4,7 (Jul 1982) 64-67. ["FRIENDS OF THE TURTLE column discusses how the turtle graphics used in Atari Pilot and Apple II Logo can be used to illustrate the concept of fractals. Includes program listings and sample runs of the program."]

78. D Thornburg, "Friends of the Turtle: Recursion - Part 2", *Compute!* 4,12 (Dec 1982) 132-137. ["The second in a series of columns dealing with recursive techniques used to generate fractals. Includes programs in Logo and Pilot used to generate several graphics which are illustrated." See Bibliography #77.]

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